m/045/017

IN REPLY REFER TO:

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
SALT LAKE DISTRICT OFFICE
2370 South 2300 West
Salt Lake City, Utah 84119

3809
(U-027)
U27-86-08P (89-1A)

DOGM
MINERALS PROGRAM
FILE COPY

24 OCT 1989

RECEIVED
OCT 27 1989
DIVISION OF
OIL, GAS & MINING

CERTIFIED MAIL P 760 542 030
RETURN RECEIPT REQUESTED

DECISION

Glenn Eurick :
Barrick Mercur Gold Mine :
P.O. Box 838 :
Tooele, Utah 84074 :

Mining Plan-of-Operations

Receipt of your request to modify the decision which approved the Sunrise dump in acknowledged. The amendment is approved with the following requirement to reduce erosion on the 2:1 dump slope.

1. Immediately following application of topsoil to the dump all 2:1 slopes are to have nylon netting or a similar erosion control product placed on the topsoil. The netting is to be fastened to the dump in a manner which insures that the netting stays in contact with the topsoil.

2. Following placement of the netting, the dump is to be hydromulched. The hydromulching is to be completed while the soil is still loose, i.e. within a few days of topsoil application in the fall.

3. Reclamation of the upper dump slope is to be accomplished concurrently with mining as soon as feasible.

You have the right to appeal to the Utah State Director, Bureau of Land Management in accordance with 43 CFR 3809.4. If you exercise this right, your appeal, accompanied by a statement of reasons and any arguments you wish to present which would justify reversal or modification of the decision, must be filed in writing at this office within 30 days after the date of this decision. This decision will remain in effect during appeal unless a written request for a stay is granted.

DEANE H. ZELLER

Deane H. Zeller
District Manager

cc: Wayne Hedberg

M/045/017

Original & map drawing was put in the revision binder

BARRICK MERCUR GOLD MINE

September 21, 1989

DOGM MINERALS PROGRAM FILE COPY

RECEIVED SEP 27 1989 DIVISION OF OIL, GAS & MINING

Mr. Deane H. Zeller
District Manager
U.S. Department of Interior
Bureau of Land Management
Salt Lake District Office
2370 South 2300 West
Salt Lake City, Utah 84119

Attention: Steve Brooks

Dear Mr. Zeller:

Subject: 3809 (U-027)
U27-86-08P
Request for Modification of Decision

Pursuant to your letter dated July 19, 1989, please find attached the requested information pertaining to our evaluations and cost estimates for constructing the Sunrise Dump. These documents inlcude:

Attachment 1 - Sunrise Dump Cross Section
Attachment 2 - Options on Construction of Sunrise Dump
Attachment 3 - Surface Mining, Open Pit Mine Planning, Moving the Earth, Bureau of Mines Information Circular 1977, (Supporting Safety in Down Grade Truck Haulage).

In response to the listed criteria of your July 19, 1989 letter, please find below the discussion to each item:

Item 1: We feel that the configuration of the Sunrise Dump design (Attachment 1) will be easily reclaimable by providing hydroseeder access benches each 100 vertical feet (200 slope feet). Additionally, this design increases the stability of the dump by building the lower dump section from the 7400 foot elevation using the wrap around dump configuration, leaving an ultimate 50 foot bench at the 7400 foot elevation, and completing the upper section from the 7500 foot elevation, following the completion of the lower section of the dump.

Item 2: Application of topsoil would be on final dozed dump slopes of 2.0:1 which maximizes the tonnage of waste applied to the dump and minimizes the surface area disturbed in Wild Horse Canyon (see Item 3 below).

Item 3: This proposed dump design will reduce major earth moving at the end of dump use, by approximately 150,000 tons dozed, compared to our previous design, and by 550,000 tons dozed compared to the 2.5:1 slope design, with the cost reduction of $25,500 savings and $110,950 savings respectively (see Attachment 2).

Item 4: In order to place the required tonnage on the Sunrise Dump and reduce the dump to a 2.5:1 slope, it would require the additional consumption of approximatey 20 acres of currently undisturbed land. We feel that land disturbance should be minimized whenever practiceable.

In response to your comments of wrap around dumping and safety concerns, we are proposing to use a wrap around dump method to the 7400 foot elevation and free dumping from that elevation, with plans to reduce the slope to a 2.0:1 upon completion. It is our opinion that ramping down to an elevation lower than the 7400 foot elevation would be an unsafe practice, due to the excesive negative grade of greater than ten percent required to access lower elevation in the limited available area (see Attachment 3).

In reference to Singhal (E&MJ, June 1988) Waste Dump Reclamation, that you enclosed with your July 19, 1989 letter, it states that final dump slopes should not exceed angles greater than 27° (1.96:1). In response, we agree with this practice and are proposing final slopes of 2.0:1.

We feel this information will provide for an environmentally sound ultimate configuration of the Sunrise Dump, and would appreciate your timely approval. Please note that the afore-described reclamation and configuration is unique to the Sunrise Dump, due to its location and public visibility, and is not applicable to the balance of the waste rock dumps at the Mercur Mine.

Barrick continues to welcome the Bureau's cooperation on this and other issues relating to our Mercur operation. Please contact Mr. Dave Beatty or myself should you have any additional concerns.

Respectfully,

G Eurick

Glenn M. Eurick
Environmental Affairs Coordinator

GME:ms

cc: F. D. Wicks
C. L. Landa
T. B. Faddies
M. P. Richardson
R. R. Sacrison
R. D. Collard
D. P. Beatty
L. Braxton (D.O.G.M.)
J. Urbanik (Tooele County)

BARRICK MERCUR GOLD MINE

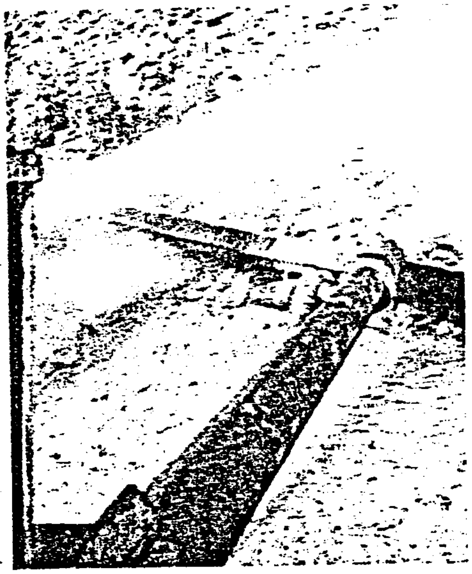
OPTIONS ON CONSTRUCTION OF [illegible]

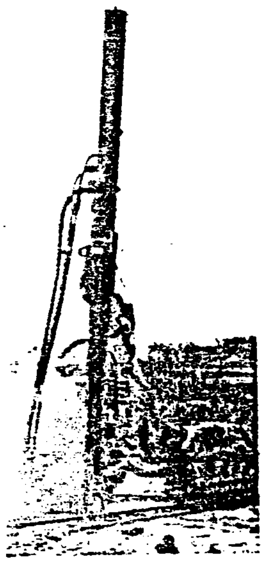
	1.5:1	2.0:1	2.5:1	7400 RAMP W/DOZING **
TONS LOST	0.00	1,500,000.00	3,100,000.00	1,350,000.00
TONS TO DOZE	0.00	250,000.00	700,000.00	150,000.00
COST TO DOZE ($)	0.00	59,500.00	145,350.00	35,000.00
D-9 REQ. TO DOZE (MNTHS)	0.00	[illegible]	[illegible]	[illegible]
TIME TO DOZE HAUL ROADS (MNTH)	0.14	0.14	0.14	0.14
COST FOR HAUL ROADS ($)	6,900.00	6,900.00	6,900.00	[illegible]
TOTAL COST	6,900.00	64,400.00	[illegible]	[illegible]

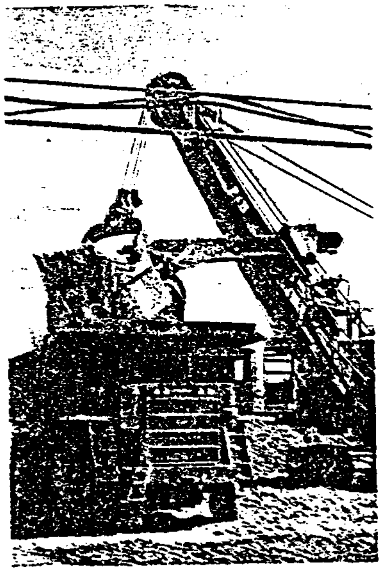
NOTE: [illegible] $[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

MUDD series



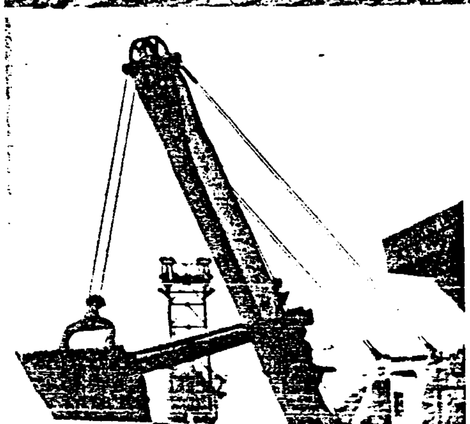




SURFACE MINING

EDITOR

EUGENE P. PFLEIDER



Rdx

10.4

Road and Property Maintenance

Gene Long[1]

10.4-1. Load Design and Construction. Surface mine haulage roads are used for transporting raw products to the mine site, preparation plant, or loading facilities, and to provide personnel and equipment an access to the pits and mine area. All of the aspects of highway engineering, including minimum slope inclines, properly banked curves, and adequate drainage, must be followed to facilitate construction of safe and efficient haulage roads for fast and economical transportation of the mined product to its destination. By maintaining good haulage roads, both truck and equipment maintenance will be kept to a minimum, resulting in reduced mining costs and subsequently higher profits.

TABLE 10.4-1
SUGGESTED DESIGN CRITERIA

Design Speed, mph	<10	10–20	20–30	30–40	40–50
Maximum sustained grade	9%	8%	8%	7%	6%
Minimum radius of curvature, ft	50	150	300	600	1000
Superelevation, ft per ft of width	0.04	0.05	0.06	0.06	0.05

There are several basic considerations in haulage road planning. Most important, one must follow all safety procedures in both design and construction of the roadway. A maximum effort should be made to follow current mining plans when laying out and planning haulage roads (aerial photographs can be extremely useful in planning and routing of roadways). Grades, road widths, and curves must be maintained within limits of present and/or planned haulage equipment specifications, since all these factors can limit speed, and hence production (Table 10.4-1). Grades in most mining operations are adverse (against the loaded haul), which increases haul cost per mile. Operators must balance these increased costs against decreased distances effected by steeper grades, and the increased construction costs of flatter roads. In general, grades should be kept as low as practicable, and should rarely exceed 10%. In those areas where ice and snow can be a problem, grades should be held to 5%.

[1] General Manager, Land Use and Conservation Department, Traux-Traer Coal Company, Division of Consolidated Coal Company, Fiatt, Illinois

Road widths are determined by the type and size of equipment and desireable speed. Serious consideration should be given to providing passing lanes on long adverse grades and in places where the line of sight is seriously impaired. This may be especially important in those instances where a mixed spread of equipment with differing capabilities is used. When curves have a small radius of curvature, widening of the inside shoulder may be necessary to accomodate the large trucks commonly found in most mines today. On fills, road width should also be increased by an amount proportionate to the height of the fill.

Curves should be constructed with the maximum radius permissible under the conditions, and they should be as flat as possible. Switchbacks should be avoided except where a material saving in construction costs can be effected or where it would be otherwise impossible to reach an objective by the use of a maximum sustained grade. Sharp curvature is one of the reasons for early obsolescence of roadways. By the use of superelevation, large flat curves can later be designed for the higher speeds possible with more modern equipment.

Superelevation of curves increases allowable speeds because of the increased ease in making sharp turns. On ascending grades, and in areas subject to ice and snow, superelevation should be reduced; otherwise slow moving vehicles may slide crossways. Excessive superelevation will also cause excessive tire wear since the loads will be shifted to the inside tires.

The final design will be determined by the estimated length of time that the road will be in use, and by what type of equipment will travel on the road. If shovels or other heavy equipment will have to be moved over the haulage roads, the sections affected by the excessive loading must be reinforced accordingly. The substitution of a series of culverts for a bridge will sometimes result in higher initial investment; however, it will facilitate the movement of larger pieces of machinery, such as shovels and draglines, which could not be moved over a bridge. From both a cost and safety standpoint, one should avoid unnecessary crossing of hard surface roads, as well as crossings of any public road. In all aspects of the design, one must provide for future expansion and larger equipment.

During and following the planning stage of the road, preliminary field work can be accomplished using engineers for surveying, determining grades, constructing profiles, and solving drainage problems. When the final layout of the road is selected, soil samples should be obtained to determine road base conditions. Field work should also include investigation of existing availability of materials for subbase and surface construction. Whenever possible, suitable local materials should be used.

Open Pit Mine Planning and Design

Crawford, Hustrulid, editors

outlines to fit a convenient planning scale than to obscure the planning by having it on multiple sheets of paper that are difficult to relate to each other.

Finally, there is the question of how to depict the bench locations on the mine plan. Personally, I have found the use of bench centerlines or midbench contours to be the simplest and most straightforward way to represent the shape of the mine. There is seldom the necessity to depict toes and crests of each bench except for illustration to people who are unused to looking at planning maps or for certain other specific purposes. Usually, it is easy for people working with the maps to get accustomed to visualizing the toe and crest locations, and the mine map draftsmen can easily develop toe and crest lines for making field notes for layout work. The drawing in Fig. 3 illustrates a mining plan composite map. It shows the bench centerline contours at the end of a year, indicating the haul roads, stripping area, and part of the waste dumps. Outside of the pit area, the contours are labeled with their true elevations; inside the pit, the elevations refer to the bench toe elevations, and the bench centerlines are one-half the bench height above the labeled elevation. In other words, it is the flat areas between centerlines that are labeled. On ramps, the bench centerlines cross the ramp halfway between benches, and the labels are at the actual bench elevation on the road. To those who are accustomed to using toes or crests, this may at first seem confusing, but in the long run, the ease of relating these composite maps to the bench maps for measuring and the simplicity of the picture offset any initial problem with labeling.

Roads

The planning of roads is one of the most important aspects of open pit planning. Because of their effect on everything to do with the pit, road considerations need to be worked into the planning at as early a stage as possible. Roads are difficult to include in some of the computer pit generations. For this reason, they are sometimes left out of the early economic evaluations. Pits can be designed without consideration of roads but it has been my experience that even after an economically optimum pit is designed, if roads are absent, the changes required to bring the pit into a realistic mining configuration are often drastic in terms of tonnage as well as in the shape of the pit.

In rail pits, which were common in the previous generation, a great deal of attention was given to the layout of rail haulage. The fact that railroad operations are not as flexible as truck operations forced this kind of planning to be dominant. Now, with the advent of truck haulage, some things can be done more easily in less room with more force fitting of haulage than was possible with railroads. As a result, road design is sometimes neglected in long-range planning. Someone has to come to grips with roads at some point, and the long-range planner is really letting down on the job if he leaves it to the mine superintendent and his staff. He is reducing his own credibility and is forcing the decision-making process into the short-range phase where the decisions sometimes do not adequately reflect the long-range needs. If haulage and access are provided for in the long-range planning, a lot of the other problems take care of themselves; otherwise, haulage and access changes may force operations to depart from the long-range plans to the point where nobody considers such planning worthwhile. The ultimate pit design may change several times as new knowledge, additional drilling, and changes in economics force constant redesign. Nevertheless, the final road should be shown because it does give an estimate of the tonnage necessary and prevents an uncomfortable awakening to the fact that the actual mining is going to be more than initial forecasts called for.

The first thing in the layout of a new pit is to decide where the road exit or exits from the pit will be. This is dependent on the location of crusher or dump points and is greatly influenced by topography. Considerable thought should be given to selecting these exits. Depending on need, there may be one or more such exit points.

In the intermediate stages, the roads should also be thought out carefully. It is nice to develop the final road layouts as early as possible, but many roads are temporary, lasting for a period of a few months to a few years, and then they are replaced by other roads that serve new pushbacks or stages in the pit. Often it seems attractive to try to design some kind of an external haul road that will not be disturbed by the mining, but in many cases this is not practical because the connections to such a road often cause more trouble than just moving a road in the mining phases.

Mine superintendents understandably like to have more than one way in and out of the pit in case something happens to a haul road. A slide or some other disruption or just the problems of operating a road when there is mining above may cause traffic delays. Sometimes a second road is not feasible if it requires a lot of stripping, but the pit designer and long-range planner should always keep in mind a way to get the ore out if there is an interruption in the main haulage system.

In laying out roads in long-range plans, there is usually a question whether to spiral the road around [illegible] or a combination of both. Sometimes the geometry of the deposit leaves little choice, for example, when there is a gently sloping ore contact in some area that provides room to work in switchbacks at little stripping cost. The planner must take advantage of these things and always design the pit to fit the shape of the deposit. Generally speaking, it is desirable to avoid switchbacks because they tend to slow down traffic, cause greater tire wear and various maintenance problems, and are probably more of a safety hazard than spiral roads. However, if there is a low side to the pit, it may be better to have some switchbacks on that side than to accept a lot of stripping all the way to the top of the high side to provide room for a road or series of roads on that side. If switchbacks are necessary, it is important to leave enough length at the switchbacks for a flat area at the turns so that trucks don't have to operate on extremely steep grades at the inside of curves and so on. The planner should also think about the direction of traffic and some of the problems the drivers may have with visibility on switchbacks.

One of the important considerations in laying out the haul roads is width. There is a tendency either to design roads somewhat narrow to save stripping or to go the other way and design a great highway that may be too costly. Naturally, wide roads are desirable but we have to balance these against other factors. A common rule of thumb is that the design width should be no less than four times the width of the haul trucks. This allows for two-way haul truck traffic and room for an outside berm and an inside ditch if necessary. Large pits commonly have 25- to 30-m roads and there may be stretches of haul road, such as where several streams of traffic come together near a crusher, where a greater width will be desirable. Fig. 4 shows a minimum haul-road cross section for an actual truck.

Table 1 shows some typical haul-road widths as related to trucks. The design width will probably be adjusted to a rounded standard figure for basic design, subject of course to variations as at turns, switchbacks, or high traffic density areas.

Some mines have two lanes in one direction over part of the haul road. For example, they allow passing for uphill loaded traffic and keep the downhill empty traffic in a single lane. These things have to be worked out in some detail by the designer after he knows something about the shape of the pit, the equipment, and the traffic density.

The second basic consideration is road grade. In a pit where there is a considerable vertical component to the haulage requirement, the grade will have to be fairly steep to reduce the length of the road and the extra material necessary to provide the road length. However, the practical maximum is usually considered to be 10%. A number of pits operate quite well at 10% both favorable and unfavorable to the loads. If it does not cause too much extra stripping or unduly complicate the road layout, 8% is probably preferable because it gives a bit more latitude in building the road and fitting in bench entries without having some locally

Table 1. Minimum Road Design Widths for Various Size Rear Dump Trucks

Truck size *	Approx width, m	4× width, m	Design width m	Design width ft
35 ton †	3.7	14.8	15	50
85 ton	5.4	21.6	23	75
120 ton	5.9	23.6	25	85
170 ton	6.4	25.6	30	100

* Nominal size in short tons.
† Metric equivalents: 1 st × 0.907 184 7 = t; 1 ft × 0.304 8 = m.

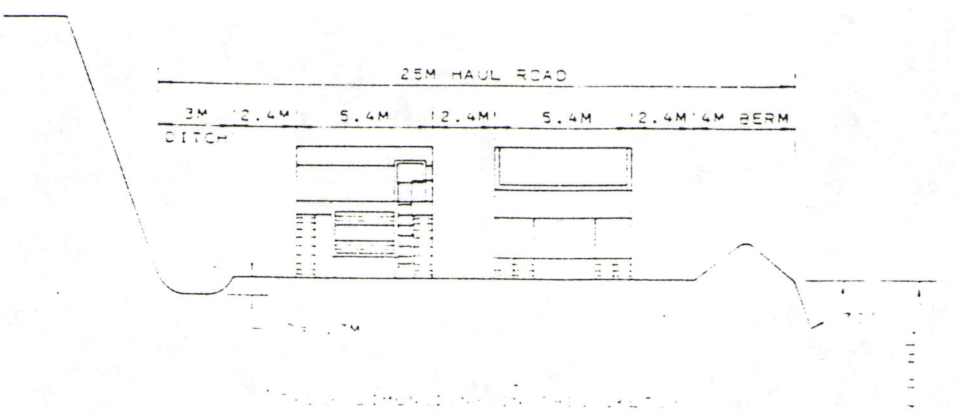


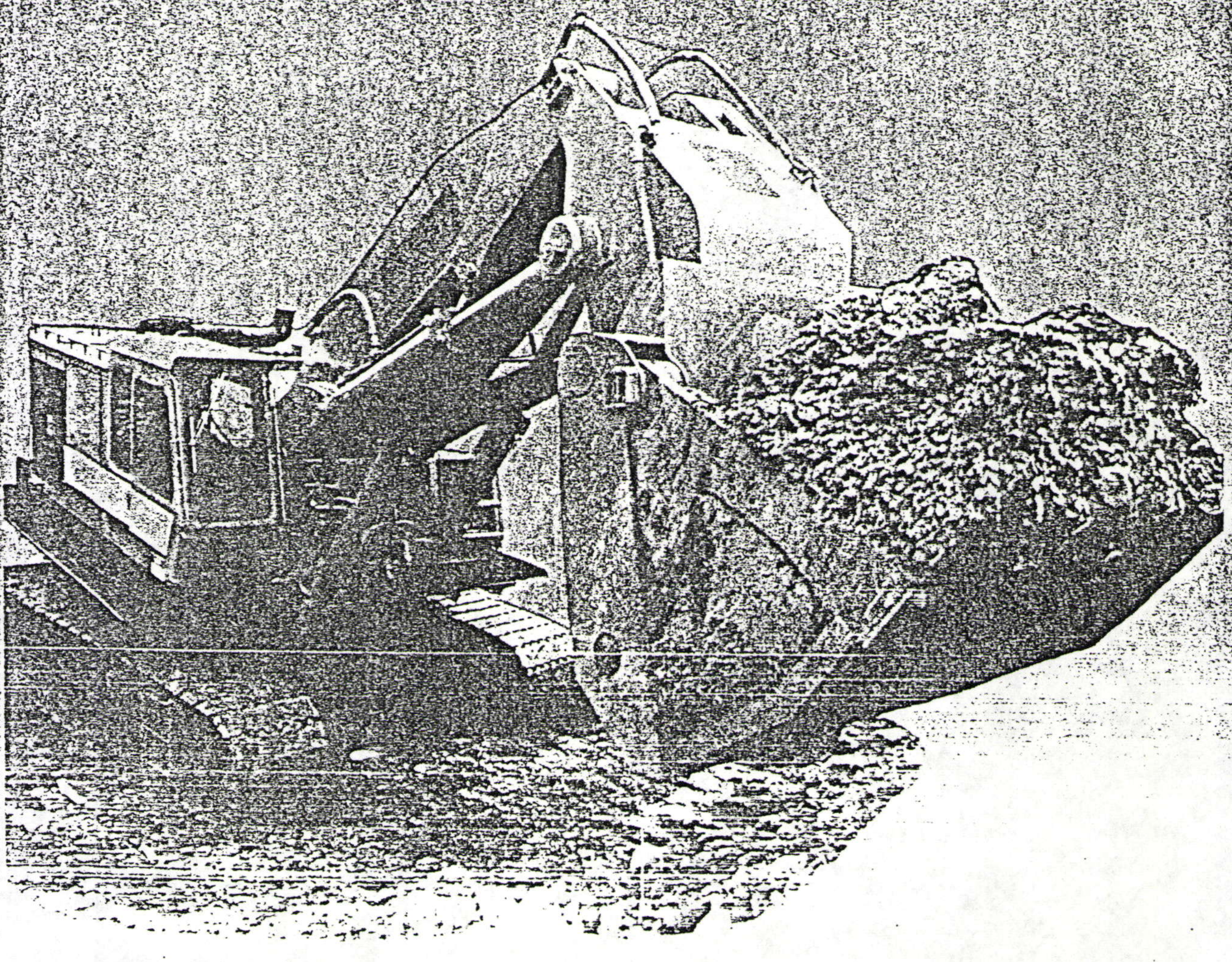
Fig. 4. Typical design haul-road width for two-way traffic using 77.11-t (35-st) trucks.

MOVING THE EARTH

THE WORKBOOK OF EXCAVATION

by Herbert L. Nichols, Jr.

THIRD EDITION



are increased disproportionately on grades over 6 per cent.

A down grade in the direction of haul (favorable grade) is helpful to about 2 per cent, but steeper grades may reduce production about as much as an adverse grade. Downhill speed must be limited for safety reasons, and even empty trucks are slowed by upgrades.

Favorable grades over 2 per cent and adverse grades over 5 per cent call for special retarding devices in torque-converter equipped trucks.

Grades may change considerably during a stripping operation. The floor of the cut moves downward, but its edges move outward and often upward. Dumps may stay at the same level, but if space is restricted they usually build upward.

Haul Routes. Two way roads for heavy hauling should be from 4 to 4½ times as wide as the vehicles using them. That is, highway trucks should have 32 to 36 feet between gutters or banks, and 11 foot off the road haulers from 44 to 50 feet. Hauling can be done on much narrower roads when necessary, but liberal width pays whenever large volumes must be moved. Even wider roads are made for some mines.

A haul route that crosses a public road is subject to serious traffic delay. For example, an automatic traffic light that is set against pit traffic, but trips within ten seconds when a truck reaches it, will delay the hauler as much as an extra 1,000 feet at 20 miles an hour. A full stop sign will cause the same or greater delays, depending on the density and speed of highway traffic.

A signal man at the intersection reduces delays to a minimum if he is allowed to favor the pit traffic.

Hillside Dump. The easiest way to dispose of stripping waste in trucks is to dump it off a bank, that is high enough so that it grows outward quite slowly. Height may be anything from ten feet to several hundred.

Such a dump may be started by flattening off a hilltop enough to give trucks sp[ace] to turn, or by cutting a pioneer road a[cross] a slope and dumping from it.

Capacity can be figured in two ways. A[n]nual or daily capacity depends chiefly [on] the length of the dumping face, and to [a] smaller extent on its height. Total capacity is the volume that can be dumped without spilling beyond the boundaries. It depends on the area than can be used, the height of the fill, and the slope of the dumped material.

Blasted rock dumped off a bank usually has an angle of repose of about 1 on 1, or 45 degrees, and is likely to stay at its original slope indefinitely unless the native soil beneath it moves outward.

Dumped soil tends to assume a somewhat flatter angle, which will depend on the size and shape of its particles. Wet soil flows, and it is important that no drainage from other areas flow into the dump. Rain falling on the turning area on the top may gully the slope and spread mud over a large area below it. This can be prevented by sloping the surface up toward the edge, keeping a berm or ridge of dirt at the edge, and providing another escape for th: water.

Both rock and soil slopes offer a hazard of rounded and oversize pieces rolling far beyond the toe of the fill. In empty country this may not matter, and brush and trees check such objects naturally. But dirt or log barriers may have to be built to prevent rolling onto paths, roads, buildings, or other property.

The slope of dumped fill is likely to be between 27 and 35 degrees, with coarser material having the steeper slopes. For rough calculations, assume that it will be 1 on 2. If the waste is already being dumped or piled, the slope can be measured for more accurate figuring of areas and quantities.

Dump Operation. Trucks are backed square to the edge and dumped. Methods of keeping them from backing over the edge

[...]dely. Sometimes the driver is just [...]ed to stop in the right spot and a[...] distance, with or without a spotter [...]mp log may be place to both indicat[e] [...]mp spot and to protect the truc[k] [...] backing too far. The chief problem [...] that a log heavy enough to stop 3[...] tons of loaded truck is difficult t[...]

[...] simplest and best protection f[...] is an 18 inch to 2 foot ridge of di[...] the edge by the grading dozer. If th[...] is very soft a ridge may be built at [...]ce from the edge.

[...] the road trucks with standard sp[...] instead of tail gates will dump the[...] clear over a ridge at the edge, so th[...] up does not occur at the top until [...] up from the bottom. Tail gate bodi[...] or may not spill part of their loads [...] top.

[...] is good practice to maintain an upwa[...] from the truck entrance to the dum[...] edge. One-half per cent is sufficient [...] [...]ous fills, and one and one-half per ce[...] sufficient for any material that is ke[...] graded.

[...] Fills tend to settle under weight of tr[...] and with time and weather. This si[...] is most rapid toward the edges that [...] built out. It is necessary to corr[...] resulting down slope with wedge f[...] avoid down slopes, that are danger[...] trucks and may cause gullying.

A wedge fill is made by dumping on [...] [...]face at the back or thin edge of the set[...] [...], and grading with a dozer to restore [...]rease the original up slope, as in Fig[...] [...]13B. The dozer first pushes toward [...] to establish the slope, then para[...] [...] to smooth and compact it, and to le[...] even windrow along the edge.

[T]OPSOIL

Topsoil is frequently the only mat[...] from a temporary pit. At other ti[...]

Any component faults detected by the operator during this type of inspection should be noted and reported immediately to the maintenance supervisor. The final determination as to the severity of a detected fault, and whether the equipment is or is not safe to operate, can best be determined by maintenance personnel.

RUNAWAY-VEHICLE SAFETY PROVISIONS

The large size of haulage vehicles precludes use of conventional vehicle arresting or impact attenuation devices to stop a runaway. In haulage operations with adverse grades, retarder failure has resulted in loss of life and substantial property damage. Some safety provisions should be incorporated into haulage road design to guard against the consequences of runaway vehicles.

The primary design consideration for runaway vehicle protection is the required spacing between protective provisions. If a runaway situation should occur, the driver must encounter a safety provision before his truck is traveling too fast to maneuver. The top speed at which the driver can maintain control (steering) of a particular vehicle is designated "maximum permissible vehicle speed." A single velocity could have been identified as the recommended maximum for all safety-provision entrances. However, the ultimate speed at which a driver can still maintain steerability and guidance of his vehicle varies according to manufacturer's design, road condition, and operator's experience. The speed to accept as a guiding criterion for the spacing of runaway protective devices can best be determined through a cooperative effort between the operators and management at each mine site.

On tables 13 and 14, distances between runaway-truck safety provisions are given for various road grades and maximum permissible velocities or terminal vehicle velocities. They apply to any type of runaway-protection device, and delineate the distance in feet required between safety-measure entrances for a truck to avoid exceeding the maximum permissible vehicle speed.

The tables illustrate differences in spacing requirements as they are affected by initial downgrade speed at the time total brake system failure occurs. Initial truck speed at loss of braking and retardation was assumed to be 20 mph for table 13 and 10 mph for table 14. Although operating speeds may vary considerably depending on policies at each mine, 10- and 20-mph initial velocities constitute a sufficient range for the grades given.

TABLE 13. - Distance between runaway truck safety provisions, feet

(Initial speed at brake failure is 20 mph)

Equivalent downgrade, percent	Maximum permissible vehicle speed or terminal speed at entrance to safety provision, mph							
	25	30	35	40	45	50	55	60
1....................	752	1,671	2,757	4,010	5,431	7,018	8,772	10,694
3....................	251	557	919	1,337	1,811	2,340	2,924	3,565
5....................	151	335	552	802	1,086	1,404	1,755	2,139
7....................	108	239	394	573	776	1,003	1,254	1,528
9....................	84	186	307	446	604	780	975	1,189
11....................	69	152	251	365	494	638	798	973
13....................	58	129	212	309	418	540	675	823
15....................	51	112	184	268	362	468	585	713

NOTE.--Equal to haulage road downgrade (percent divided by 100) minus roadway rolling resistance (pounds per ton).

TABLE 14. - Distance between runaway truck safety provisions, feet

(Initial speed at brake failure is 10 mph)

Equivalent downgrade, percent	Maximum permissible vehicle speed or terminal speed at entrance to safety provision, mph							
	15	20	25	30	35	40	45	50
1....................	418	1,003	1,755	2,674	3,760	5,013	6,433	8,021
3....................	140	335	585	892	1,254	1,671	2,145	2,674
5....................	84	201	351	535	752	1,003	1,287	1,604
7....................	60	144	251	382	537	716	919	1,146
9....................	47	112	195	297	418	557	715	892
11....................	38	92	160	243	342	456	585	730
13....................	33	78	135	206	290	386	495	617
15....................	28	67	117	179	251	335	429	535

NOTE.--Equal to haulage road downgrade (percent divided by 100) minus roadway rolling resistance (pounds per ton).

Computation of values was accomplished through the formula

$$S = \frac{\Delta V^2}{2g\ (\sin\theta\ - b)},$$

where S = distance traveled until "maximum permissible vehicle speed" or entrance to runaway truck safety provision is reached, feet;

ΔV = difference in velocity between travel speed at loss of braking and retardation and the speed of travel at safety provision, feet per second;

g = 32.2 fps^2;

θ = angle of descent, degrees;

and b = coefficient of rolling resistance (expressed as a mean value of 0.05 to encompass the majority of mine road and tire situations), dimensionless.

The following sections discuss two types of runaway vehicle safety provisions. Their spacing should be established in conformance with the recommendations set forth in the preceding discussion.

Runaway-Vehicle Collision Berms

As research into berms and runaway truck protection progressed within this project, an innovative design from Australia was investigated and found to have considerable merit. Utilizing an intermittent triangular berm constructed in the middle of a haulage road, Australian mining companies have been able to almost eliminate problems with runaway vehicles.

These runaway-vehicle collision berms are constructed of nonconsolidated screened fines and placed at crucial points within the haulage operation. If the brakes and retarder of a vehicle fail during operation, the driver alines the vehicle so that it straddles the collision berms, and rides the vehicle to a stop. This type of median design is actually a simplified form of vehicle-arresting device. The most critical design aspects of this type of berm are the spacing between the berm sections and the height of the berm in relation to the undercarriage of the vehicle. The spacing between berms must be sufficient to allow a runaway vehicle to aline itself with the berm before impact. If properly alined, the vehicle will shear off that portion of the berm above the undercarriage, expending energy through momentum transfer, rolling resistance, and frictional action until stopped. If improperly alined, the vehicle could overturn. Accordingly, adequate space between berms must be maintained to allow the driver time to position his vehicle with respect to the berm.

Typical sections of these berms with sizing and spacing criteria are shown in figures 26 and 27.

A table is provided with figure 26 to show approximate sizing for various tonnage vehicles. Ranges are given rather than specific dimensions since each berm design must be governed by the height of undercarriage and wheel track of the vehicle for which the berm is designed. Where vehicles of different sizes are operating concurrently on a haulage road, the berm should be sized primarily according to the wheel track of the larger vehicle, since smaller vehicles will be stopped on the "entrance ramp" to the berm. The simplicity and economic attractiveness of this design lends itself well to practically any haulage operation. For haulage roads with less severe grades and associated fewer problems with runaway vehicles, collision berms may be located in critical areas only.

A prerequisite to the use of berms is the ability to economically build a road of sufficient width to accommodate them. Another factor is the necessity of using screened fines in the construction. Depending upon the type of operation, a mobile crusher could be used to facilitate the construction and maintenance of the berm.

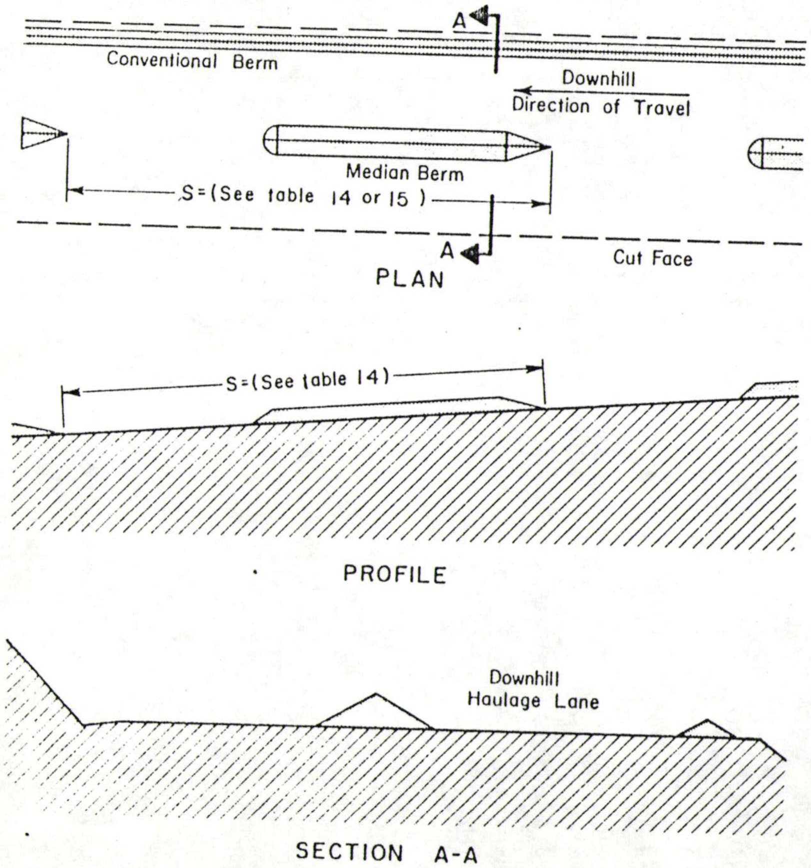
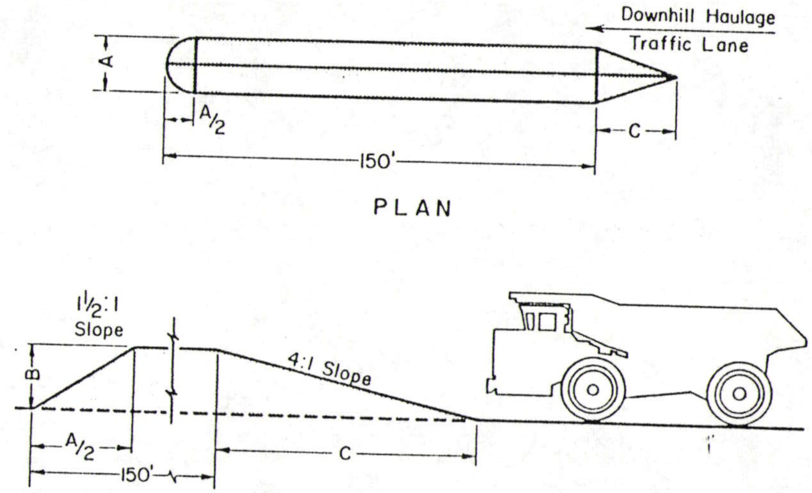


FIGURE 26. - Runaway-vehicle collision berms.



	A	B	C
CATEGORY 1 13 to 25 tons < 100,000 lb	11'-12'	3.5'-4'	14'-16'
CATEGORY 2 28 to 50 tons 100,000-200,000 lb	12'-15'	4'-5'	16'-20'
CATEGORY 3 55 to 120 tons >200,000-400,000 lb	15'-18'	5'-6'	20'-24'
CATEGORY 4 120 to 250 tons > 400,000 lb	18'-32'	6'-11'	24'-44'

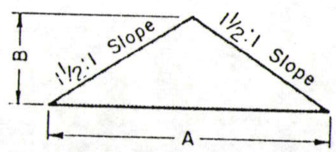


FIGURE 27. - Median application of collision berms.

Median berms are most effective at reduced vehicle velocities. The drivers of haulage vehicles must be instructed in the proper use of the median berm and taught to rely upon it as a first-line emergency maneuver and before the vehicle has accelerated beyond a reasonable speed.

At one mine site in Australia with extremely-severe grades (8% to 12%), these median collision berms have been in use for 3 years. Within that time, runaways have occurred on an average of once every 2 to 3 months. In all cases except one, the vehicles were safely stopped with usually only minor damage to the undercarriage. In the one incident where the vehicle was not stopped, the berm slowed the truck to the point where the driver could safely steer into the cut side of the bench.

Prior to incorporating this device in temperate climate areas, careful consideration must be given to required maintenance. The majority of surface-mining States experience freeze conditions during winter months. If collision berms are not protected from solidification in these periods, a vehicle could be severely damaged in an encounter. If climate at the mine site has this potential, collision berms must be constantly checked, and where freezing occurs, the berms must be agitated to achieve their former unconsolidation. In cases where freezing and/or excessive rainfall is a constant problem, a protective covering of material such as polyethylene or an alternate safety provision is recommended.

Escape Lanes

Escape lanes for control of runaway vehicles have been used extensively on mountain highways in the United States. Relatively simple in design and successful in application, escape lanes are relied upon by highway designers for use on long, sustained grades.

Escape lanes have good potential for intercepting and stopping runaway haulage vehicles. However, they may be expensive to construct and maintain, depending on site conditions. Costs incurred in construction are primarily attributed to bench excavation and roadbed preparation.

Emergency escape lanes have three basic areas of design and construction: entrance areas, deceleration areas, and stopping areas. Each of these will be discussed separately.

Entrance

The entrance from the main haulageway is perhaps the most important design and construction consideration of an escape lane. Entrance areas must be spaced according to maximum permissible vehicle speed and percent grade of the main haulage road. Included within the entrance area are vertical curve transitions, horizontal curve development (including superelevations), and lane development. Care must be taken that any horizontal curve can be negotiated by the runaway vehicle. Table 15 lists maximum horizontal curves as related to vehicle entrance speeds and superelevations. Superelevations less than 0.06 fpf or greater than 0.10 fpf are not recommended due to difficulties with curve development and drainage.

TABLE 15. - Maximum permissible horizontal curves for escape lane entrance

Superelevation, feet	Vehicle speed at escape lane entrance, mph					
	40		45		50	
	Degrees	Radius, ft	Degrees	Radius, ft	Degrees	Radius, ft
0.06/1............	12	477	10	596	8	716
0.08/1............	13	441	10	578	8	716
0.10/1............	14	409	11	235	9	637
	55		60		65	
	Degrees	Radius, ft	Degrees	Radius, ft	Degrees	Radius, ft
0.06/1............	6	930	5	1,146	4	1,432
0.08/1............	7	835	6	955	5	1,146
0.10/1............	7	796	6	955	5	1,146

Another important element of proper entrance design is lane width. The lane must be wide enough to accommodate the vehicle but not so wide as to require excessive construction effort. Recommended minimum lane widths for escape lanes are presented in table 16 for various vehicle categories.

TABLE 16. - Recommended escape lane widths

Vehicle weight, pounds	Minimum width, feet
<100,000..................	15
100,000 to 200,000.........	18
>200,000 to 400,000.......	22
≥400,000...................	29

Deceleration

The major contribution of an escape lane to deceleration of a runaway vehicle is that of reverse grade. The greater the reverse grade of an escapeway, the less length required. Table 17 relates escapeway lengths to vehicle entrance velocities and percent grade of the escape lane. The formula used in computing escapeway length is

$$S = \frac{V^2}{2g\ (\sin\theta + b)}, \tag{7}$$

where S = required length of escape lane for deceleration from entrance speed to a full stop, feet;

V = entrance speed from tables 13 and 14, fps;

g = 32.2 fps^2;

b = coefficient of rolling resistance, dimensionless;

and θ = angle of ascent, degrees.

It is important to note that a coefficient of rolling resistance of 0.2 or 400 ppt (pounds per ton) was used to compute the distances. This value is the resistance offered by an unconsolidated surface material such as sand or loose earth. Escape lanes should not be a continuation of the main haulage road, and all normal road maintenance should cease at the end of the entrance area. Escape lanes are most functional when rolling resistance is high. Poorly compacted, deep, loose, granular materials are best suited for roadbed use in deceleration areas since these materials tend to retard vehicle movement. It should also be noted that distances given in table 17 are to be applied from the end of the entrance area; that is, at the end of the horizontal and vertical curves. Also, surface material characteristic of that used on the main haulage road should be employed to the end of these curves.

TABLE 17. - Length of escape lane, feet

Grade of escape lane, percent	Vehicle speed at entrance to escape lane, mph				
	15	25	35	45	55
20..................	19	53	103	170	253
15..................	22	60	117	194	289
10..................	25	70	137	225	337
5..................	30	84	164	271	405

NOTE.--Assumes coefficient of rolling resistance is 400 ppt or 0.2.

In this manner, a safe transition from hard to loose surface can be achieved.

Stopping

After a vehicle has been slowed through the deceleration grade and high-rolling-resistance roadbed, it becomes necessary to stop the vehicle and prevent its coasting back down the escape lane. Approximately three-quarters of the way up the escape lane, provisions for stopping the vehicle should begin. Stopping or arresting techniques include the following:

1. A level section of roadway at the end of the escape lane.

2. Median Berm.--A median berm, constructed on the escape lane, is one of the most efficient means for vehicle arrest. Using the same basis for design as that presented in the previous section, median berms are well suited for use in conjunction with escape lanes.

3. Sand or Gravel or Mud Pits.--After a vehicle has been slowed down on the escape lane, a deep sand, gravel, or mud fitted pit will cause the wheels to become stuck, thus prohibiting further movement until assisted by another vehicle. This concept is very effective if properly maintained.

4. Road Bumps.--Road bumps, whether constructed by excavating trenches or establishing mounds across the lane, retard vehicle movement by trapping

in "designed ruts." Mounds or bumps must be thoroughly compacted to insure integrity under the weight of a truck.

5. Manual Steering.--If it is not practical or possible to do any of the foregoing, or if the runaway does not reach the "stopping area," when the truck comes to rest the driver should be trained to either engage the transmission in a "park" position, or set an emergency brake (if usable), or engage the transmission in the lowest possible gear and turn the wheels <u>away</u> from the escape lane berm.

Figures 28-30 depict typical plan, profile, and section views of an emergency escape lane.

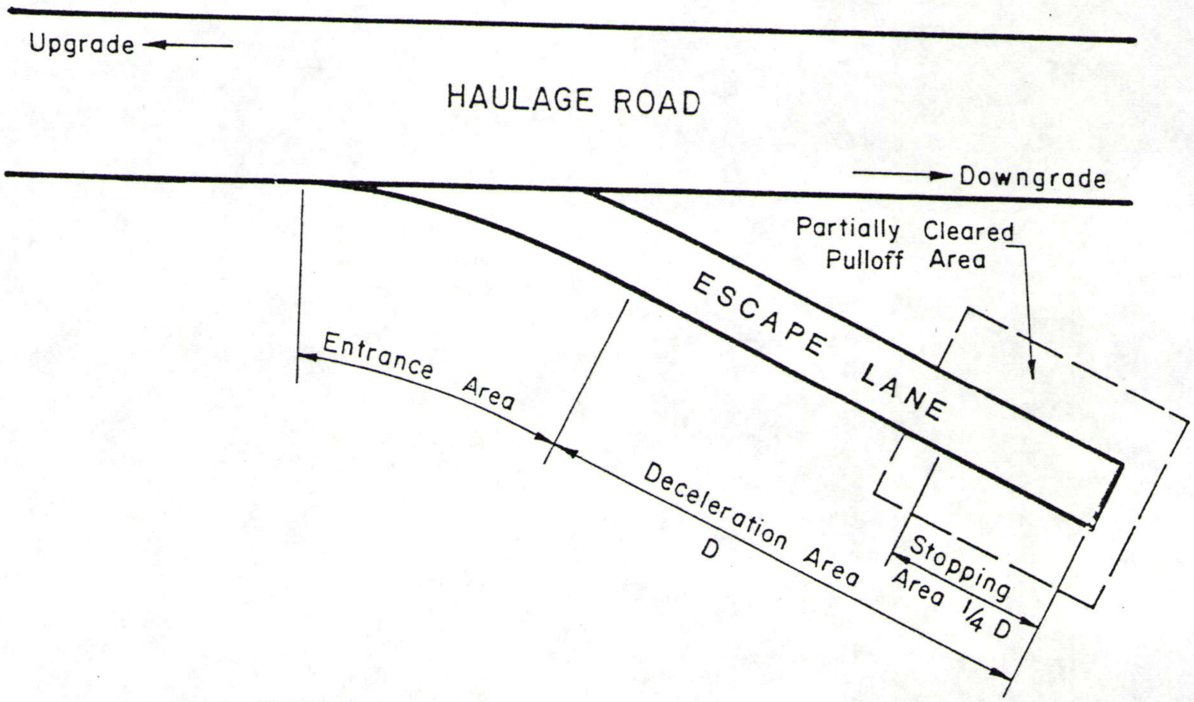


FIGURE 28. - Plan of haulage road escape lane.

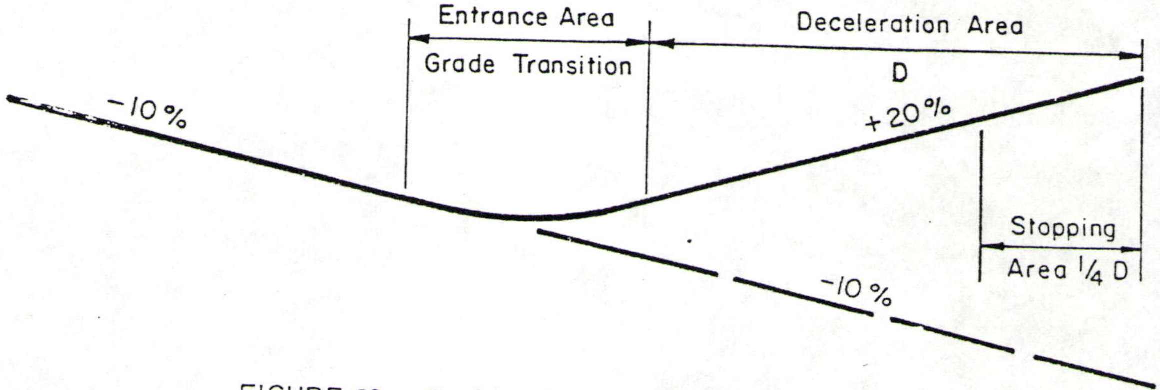


FIGURE 29. - Profile of haulage road escape lane.

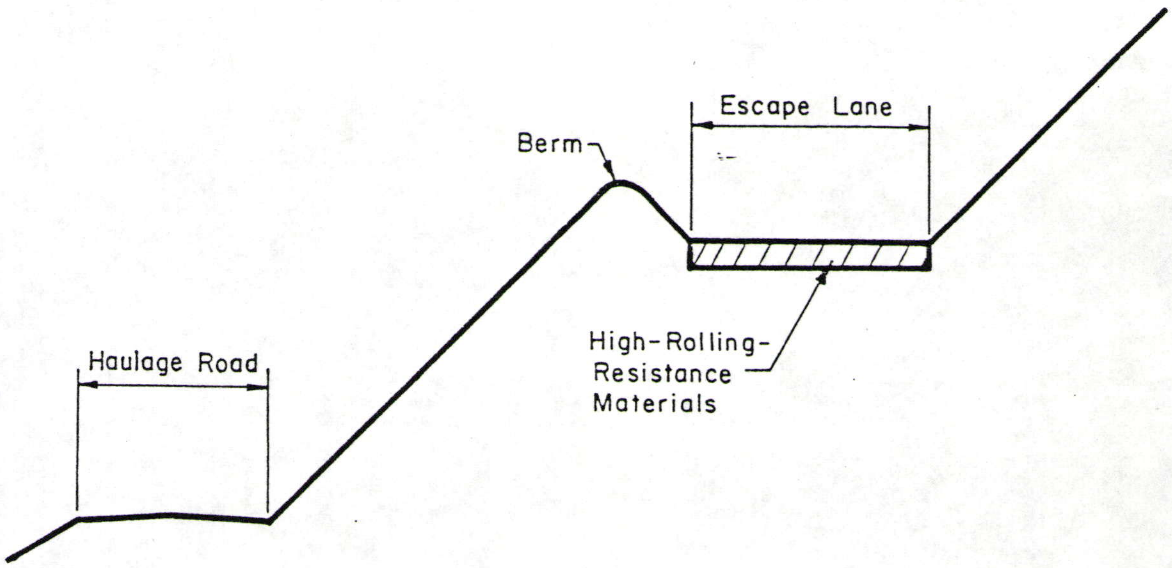


FIGURE 30. - Cross section of haulage road escape lane.

CONCLUSIONS

Surface mining, regardless of mineral commodity being sought through its inception, is a highly competitive business and, like any other business, a beneficial cost-to-profit ratio must be maintained. It is important to insure that cost efficiency does not impinge upon the intangible aspects of mining such as operator safety and proper equipment utilization. From the sites selected as being representative of typical mining operations, it became apparent that in many instances haulage road construction is not considerate of operator safety; not as a result of disregard, but rather a lack of awareness of correct design principles. The most obvious disparity between existing haulage road construction practices and criteria recommended for safety lies in the areas of alinement and drainage.

Sustained haulage road gradients at many eastern surface mines exceed the 10% maximum stipulated for safety in the Haulage Road Design Study. In most cases, the rationale for constructing a greater gradient is obvious--to keep haulage distances as short as possible through steep mountainous terrain. Superelevation on curves, tangent roadway cross slopes, and vertical curves at grade crests are other design factors seldom applied.

In general, application of adequate roadway drainage provisions are also lacking. Severely scoured and rutted road surfaces, roadside ditches eroded to excessive depths, water-filled depressions in the roadway, and unstable or slippery road segments are common sights throughout the eastern surface-mining region.

As illustrated by table 18, costs associated with haulage road construction to remedy safety hazards such as those mentioned can be considerable. At the surface coal mine sites, for example, construction expenditures exceed \$200,000. It must be noted, however, that the haulage roads of each of the